

# NANOCRYSTALLINE DIAMOND FILMS FOR SURFACE ACOUSTIC WAVE DEVICES

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## Abstract

Surface acoustic wave (SAW) devices are critical components in wireless communication systems. In this work, the potentialities of nanocrystalline diamond films as high velocity and low propagation losses substrates for high frequency SAW devices are investigated from an experimental and theoretical point of view.

## INTRODUCTION

The high acoustic phase velocity of chemical vapor deposited (CVD) diamond makes it, when combined with piezoelectric films such as AlN or ZnO, very attractive for high frequency (GHz range) surface acoustic wave devices. However, the processed diamond based SAW devices suffer from relatively low performances mainly due to the important propagation losses in polycrystalline structures. According to previous study, the propagation losses decrease while the diamond grain size diminishes<sup>1,2</sup>. Therefore, the very small grain size of nanocrystalline diamond makes it an hopeful alternative to the commonly used polycrystalline diamond, as illustrated in preliminary study<sup>3</sup>. In the present work we investigate the structural and electrical properties of nanocrystalline diamond films and their potentiality as SAW device substrates by both experimental and theoretical approaches.

## RESULTS

Very low surface roughness nanocrystalline diamond (NCD) layers were deposited on silicon substrates by microwave plasma assisted CVD (MPACVD) process. Both continuous wave (CW) and pulsed wave (PW) were employed with Ar/H<sub>2</sub>/CH<sub>4</sub> gas mixtures in order to obtain films of different thicknesses with grain size varying between a few nanometers and a few tens of nanometers. The various characteristics of the elaborated films were principally investigated through SEM, AFM, TEM, Raman spectroscopy and XRD.

Highly oriented piezoelectric aluminum nitride films were grown by RF reactive magnetron sputtering on the NCD substrates. Aluminum inter-digital transducers (IDT) were patterned by photolithography technique on AlN films or at the AlN/NCD interface, depending on the configuration considered for the layered structure. Dispersion curves of elastic velocity and electromechanical coupling coefficient were determined for the both structures AlN/IDT/NCD/Silicon and IDT/AlN/NCD/Silicon, and for various NCD films properties, from the high frequency characterization of the SAW devices.

The phase velocity ( $v_\phi$ ) was determined from the peak's frequency  $f_i$  using the following equation:

$$f_i = \frac{v_\phi}{\lambda} \quad (1)$$

where  $\lambda$  is the wavelength of the acoustic wave and is fixed by the spatial periodicity ( $P$ ) of IDT and the order of the considered harmonic ( $n$ ):

$$\lambda = \frac{P}{n} \quad (2)$$

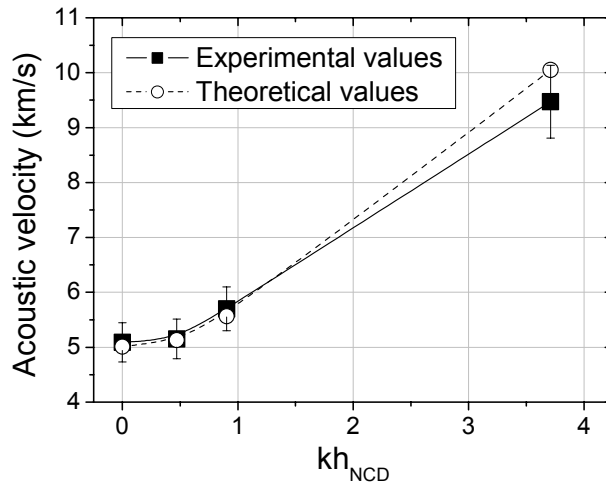
The harmonic peak intensities are governed by the metallization ratio of IDT.

The propagation losses were determined by measuring the insertion losses ( $\alpha_i$ ) of SAW devices showing identical geometry except the propagation distance, i.e. the gap between input and output IDT. The propagation loss ( $p$ ) can be then expressed in dB/ $\lambda$  by:

$$p = \lambda \frac{\alpha_2 - \alpha_1}{gap_2 - gap_1} \quad (3)$$

where  $gap_1$ ,  $gap_2$  and  $\lambda$  are expressed in  $\mu\text{m}$  and  $\alpha_i$  in dB.

The experimental results are in satisfactory agreement with the theoretical predictions of a model developed for layered structures. In particular, they show that a high surface acoustic velocity, close to  $10^4$  m/s for some devices, may be obtained by using NCD layers. As an illustration, Fig. 1 shows the acoustic velocity estimated on IDT/AlN/NCD/Silicon layered structures as a function of  $kh_{\text{NCD}}$ , where  $k$  is the wavevector modulus and  $h_{\text{NCD}}$  is the thickness of NCD films.



**Figure 1:** Experimental and theoretical values of the acoustic velocity determined for SAW devices achieved on IDT/AlN/NCD/Silicon layered structures as a function of  $kh_{\text{NCD}}$ .

## REFERENCES

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